Online Resource 1: literature and novelty searches

Article: How much of a finite sample can a microchannel surface sensor capture? Optimal flow rate, universal capture map and closed-form design rules. Journal: Microfluidics and Nanofluidics. Author: Ananya Sharma, MIT School of Bioengineering Sciences and Research, MIT Art, Design and Technology University, Pune, India (ananya.sharma.pune@gmail.com).

Searches were run on 15 October 2026 with the Europe PMC REST API (title/abstract fields) and Crossref relevance search. The screened abstracts and raw outputs are available from the author.

1. What already exists

Work	What it established	What it did not do
Squires, Messinger & Manalis 2008 (Nat Biotechnol)	Scaling theory of convection–diffusion–reaction for surface sensors; Lévêque flux; "full collection" regime when the Péclet number is small; rules of thumb for collection rate and equilibration time	No fixed-volume / fixed-time optimisation; no captured *fraction* of a finite sample; no recirculation analysis
Parsa et al. 2008 (Lab Chip)	**The closest prior work.** Computation + experiments showing that finite sample volume and assay time create a "reagent-limited" regime, a "critical flow rate" (0.5 µL/min for their conditions) giving maximum signal at shortest time, and that a short concentrated plug (5 µL, 100 nM) beats a long dilute one (50 µL, 10 nM)	Results are case-specific (one geometry, one chemistry); abstract gives no dimensionless criterion, no general map of captured fraction, no closed form, no recirculation bound. Only the abstract was available to me, so only what the abstract states is used
Zimmermann et al. 2005 (Biomed Microdevices)	Finite-difference model of microfluidic surface immunoassays; flow velocity can be optimised for sensitivity, volume or speed	Case-specific optimisation; no universal groups
Chou et al. 2012 (Lab Chip)	Porous-bead sensors: an optimal flow rate exists under limited volume and time; recirculation overcomes the limit	Porous-bead geometry, constant-pressure constraint; no closed form
Miller et al. 2018 (Anal Chem)	Paper-based flow-through: matching capture time scale to residence time for large-volume processing	Porous paper, not microchannel surface capture
Hofmann et al. 2002 (Anal Chem)	Hydrodynamic confinement cuts sample consumption 96%	Specific device; no optimisation theory
Lynn et al. 2013 (Lab Chip)	Flux scales as H^(-2/3) at fixed flow; 4-fold LOD gain from 47 to 7 µm	Fixed flow rate, unlimited sample
Vijayendran et al. 1999; Glaser 1993; Myszka et al. 1998; Hu et al. 2007; Gervais & Jensen 2006	2D convection–diffusion–reaction models, two-compartment approximations, kinetic-constant extraction	Unlimited sample; focus on kinetics or binding rate, not on fraction of a finite sample captured
Ekins 1989/1998; Saviranta et al. 2004	Ambient-analyte theory: in static microspot assays <2% of the analyte is captured	Static incubation, not flow-through

Work	What it established	What it did not do
Sheehan & Whitman 2005; Nair & Alam 2006	Transport limits detection by nanoscale sensors	Diffusion-limited single sensors; no finite volume–flow trade-off

2. Queries and hit counts (Europe PMC, TITLE_ABS unless stated)

Query (abbreviated)	Hits	Relevant hits
"sample volume" AND "flow rate" AND "capture" AND "microfluidic" AND ("mass transport" OR "diffusion")	0	–
"sample volume" AND "flow rate" AND (biosensor OR immunoassay) AND (mass transport OR diffusion OR convection)	0	–
("fixed/finite/limited volume" OR "finite sample") AND "flow rate" AND (capture OR binding)	4	Parsa 2008; Chou 2012
("limited/finite sample volume") AND (binding OR capture)	14	Parsa 2008
"optimal flow rate" AND (biosensor OR immunoassay OR SPR)	4	Chou 2012
"capture efficiency" (title) AND "flow rate" AND (biosensor OR immunoassay)	0	–
(capture/collection efficiency OR fraction captured) AND microchannel AND antibody/biosensor AND flow rate	5	none (all cell capture)
("fraction of analyte" OR "capture fraction" OR "analyte utilization") AND (microfluidic OR biosensor)	0	–
(Damköhler AND Péclet) AND (biosensor OR immunoassay)	2	none on finite volume
(Lévêque OR Graetz) AND (biosensor OR immunoassay OR capture)	1	none
recirculat* AND biosensor AND capture AND flow	2	Chou 2012
"assay time" AND "sample volume" AND "flow rate" AND surface AND (model OR simulation)	0	–
Papers citing Parsa et al. 2008 (Europe PMC citations endpoint)	50	Chou 2012; Miller 2018; Galvin 2018 (total capture, nanofluidic); Escobedo 2010; Fu 2009. None proposes a general dimensionless optimum or captured-fraction map from titles/abstracts
Crossref relevance search, 5 queries (top 15 each)	–	Nothing overlapping (`lit/cr_out.txt`)

3. The gap

The *existence* of an optimum flow rate under finite volume and time is **not new**: Parsa et al. (2008), Zimmermann et al. (2005) and Chou et al. (2012) all report it for specific devices. What I could not find in any search is:

1. a general statement, with its condition, that the optimum is Q* = V/T (deliver the sample over

exactly the available time) whenever the capture rate Q·G rises with Q, i.e. whenever the

per-pass capture fraction G is concave in the Graetz variable;

2. the reduction of the best achievable captured fraction f* to a two-parameter universal map in

Ω = DWLT/(HV) (the Graetz variable evaluated at Q*) and Da = k_on b_m H/D, with κ = ΩDa as the

kinetic group;

3. an explicit closed form for f* accurate over the whole map (transfer-unit combination of a transport ceiling and a kinetic ceiling), so the design question can be answered without CFD;

4. the quantitative penalty for running at the wrong flow rate (N ∝ (Q/Q*)^(-2/3) above Q*);*

5. the bound that recirculation can only raise capture to the kinetic ceiling 1 − exp(−κ), and the corresponding conversion of f* into a detection limit for sub-picomolar biomarkers.

4. Why this paper fills it, and what it does not claim

- It is a computational study, validated against analytic limits (Lévêque, Graetz/Shah–London

Nusselt number, reaction-limited and Langmuir limits) and checked for consistency with the

published experimental trends of Parsa et al. (2008) (concentrated plug wins) and Lynn et al.

(2013) (H^(-2/3) flux scaling, 4-fold LOD gain).

- It does **not** claim to have discovered the optimum flow rate; it credits Parsa et al. and

others for that and positions itself as the general, dimensionless version with closed forms.

- No wet-lab data. Neurofilament light / p-tau217 appear only as motivation for the detection-limit

arithmetic.